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Oil and the Future of Marine Corps Aviation

“What has been is what will be, and what has been done is what will be done; and there is nothing new under the sun”... Ecclesiastes

Few commodities have the immediate ability to affect our national security, the national economy, and our personal lives like oil. As the average price per barrel of oil recently hit an all time high of over \$68.00 per barrel and gasoline prices topped \$3.00 a gallon many Americans were once again driven by economic concern to question our Nation’s energy policies.¹ Every President since Nixon has had to deal with some form of energy shortage or volatile price fluctuations. However, several factors make today different from the past. First, despite studies conducted and congressional hearings both of which pose viable solutions, we consistently have failed to act upon them, refusing to learn from our past experiences. Secondly, oil prices are unlikely to decrease as they did in the late nineteen eighties and nineties when oil bottomed out at \$10 dollars a barrel. Third, world demand for oil is projected to increase 47% by the year 2030 to 118 million barrels a day. China and India’s rapid economic growth alone is responsible for 43% of the 47% increase.² (See Appendix 1, Figure’s 1 and 2)

A geological possibility is looming before us that would dramatically complicate this problem; it is a theory known as Hubbert’s Peak. The Hubbert’s Peak theory posits that at a point in the future we will reach peak oil production after which the world’s liquid oil production will begin to decrease significantly³, just as the worlds demand for oil is increasing. This theory will be examined in more detail below.

Unconventional fuels created from coal, tar sands, and oil shale are a potential resource of fuels for the Department of Defense, but the nations ability to convert these minerals into a usable fuel exists only in experimental scale plants.⁴ Even if the capability is developed, the

underlying increased cost of producing unconventional fuel will have to be absorbed by the users in the form of higher costs.⁵

The whine of the turbine, the roar of the jet, the thumping of the rotor blade all go silent without oil. It is the strategic and tactical life blood of all the armed services and its supply is most tenuous to the U.S. This paper will examine the impact on Marine Aviation, the one element of the Marine Air Ground Task Force most dependent on oil.⁶ The impact of higher oil prices will be significant in terms of maintaining training and readiness. Higher prices combined with decreasing supply have the potential to cripple Marine Corps Aviation. Congress and the Department of Defense (DOD) under the impact of economic and budgetary pressure may even look to significantly restructure aviation within the armed services.

Hubbert's Peak Oil Theory

In the 1950s the United States was the leading producer of oil in the world. Much of the nation's industrial, military and political might derived from its giant oil industry. In 1956 Marion King Hubbert, a geologist working for Shell Oil Company predicted the U.S. crude oil production would peak in 1972. Hubbert also made public his projection that American oil dominance would soon come to an end. Hubbert's theory was rejected by almost everyone inside and outside the oil industry. The controversy raged until 1970, when U.S. production of crude oil began to decline and Hubbert's theory was proven correct.⁷

In simplistic terms Hubbert's Theory is based on the traditional mathematical bell curve (figure 3). Hubbert reasoned that any mineral found in a particular site has a finite amount associated with it. In Hubbert's case he was looking at oil. Hubbert knew that anytime a new oil field was discovered production would rapidly increase toward peak production (50%), at which time production from the oil field would then begin to decrease. By applying his ideas to data on

existing oil fields he was able to refine and improve upon his calculations. Hubbert then calculated existing reserves of all the known oil fields in the United States, estimated technological improvements that would increase output, and calculated that U.S. oil production would peak in 1972. His prediction was off by only two years. In the very same presentation, Hubbert also predicted that world crude oil production would peak in the year 2000.⁸ (See appendix 1: figure 3).

In 1995, several analysts began to take a second look at Hubbert's Theory of world oil production. Most analyst calculated that peak oil production would occur between 2004 and 2008 based on current data.⁹ Using table (1) in appendix 1 and several other sources, for the purposes of this paper the year 2016 will be used as the estimated peak production for the world's crude oil. In table (1) there is a wide variety of opinion as to when Hubbert's peak reached but not about the underlying notion that peak production will occur. Note that the table does not include a complete list of advocates of "Hubbert's Peak" Theory.¹⁰ In addition to the usual grouping of geologists, the list also includes a major oil company and the Energy Information Administration of the United States Department of Energy.

It is important to understand that Hubbert's theory does take into account technological innovation, and allows for greater exploitation of existing wells, as well as the discovery of new oil fields. "Peaking" is not running out of oil, it is the maximum production of crude oil, from which point global crude oil production will thereby decrease. This is a liquid fuel problem not an "energy problem." These estimates are based on the reporting of each nation's reserves. Also taken into account is that United States reserve estimates are considered to be reasonably accurate, while foreign estimates are less likely to be so for both political and technical reasons.

Thus, the reasons for the variations in analyst estimates for the date peaking occurs is directly attributed to which oil reserve estimates they used in their calculations.

Counter-arguments to Hubbert's Peak

Hubbert's Peak Theory is not without its detractors. Many people argue that analysts advocating Peak Oil Theory do not acknowledge data or research which contradicts their theories thus implying they can't explain the inconsistencies or weakness of their work. Because of the complexity of world oil production, there is always some data which can support alternative viewpoints. The main arguments against the timing of Peak Theory revolve around the differing methods used to forecast oil supply. The differing methodologies used are also flawed by certain repetitive errors, namely: (1) bias, and especially pessimism is at work since nearly every forecast has been too low since 1978, despite the reliance on price assumptions that were much too high; (2) Similar oil production forecasts for every region, despite different fiscal systems, drilling levels and/or the maturity of the industry, suggest omitted variables; (3) Misinterpretation of recoverable oil resources as total resources by using a point estimate instead of a dynamic variable, growing with technology change, infrastructure improvements, etc.; so that (4) there is a tendency for all national, regional or non-OPEC production forecasts to show a near-term peak and decline, which has always moved outward and higher in later forecasts (the opposite of price forecasts).¹¹

Many advocates of the peak oil theory argue that "no major oil fields have been discovered since 1968." This has recently been proven to be an inaccurate statement as both Mexico¹² and the United States have recently discovered deep water oil fields in the Gulf of Mexico that have the potential to increase both countries' liquid oil reserves by 50 percent.¹³ Thus, the potential is always present that the discovery of previously unknown oil fields can

change peak oil calculations. However, deep water oil fields are very expensive to operate; therefore, oil prices must remain high in order for the fields to be economically viable.

Synthesis of Theories and Reality

Many people may remember how in the 1970s scientists predicted the next Global Ice Age, which was later shown to be erroneous despite widespread “scientific” consensus at the time. Today, Global Warming advocates want us to believe they are not sailing on the same ship as their Ice Age predicting brethren. Peak Oil theorists today also find their position to be problematic; despite “scientific” consensus in predicting peak oil they too have been proven wrong before. The problem in predictions lies in the incredible complexities involved when trying to determine the world’s total oil supply or when Global Warming theorists attempt to predict the impact of pollutants and CO₂ on global weather. The naysayers to both theories are in good company with historical realities, therefore many have taken the attitude that the Peak Oil advocates are simply “crying wolf.” However, one underlying factor does not change in almost every prediction and that is that the price of oil will continue to increase. Whether or not you subscribe to Peak Oil Theory in ten years or fifty years or not at all, demand for oil is very unlikely to decrease. New oil fields may continue to be found, but they will likely be in far more inhospitable and thus more costly locations like the deep ocean. Thus, the Department of Defense, the Marine Corps, and our sister services will all be paying more tomorrow to conduct the same level of training and operations that we do today.

Alternative or Unconventional Fuels

Attempts to find an alternative fuel for aviation to date have produced limited results.

While ethanol, hybrid electric engines, bio-diesel, hydrogen, fuel cells and compressed gases may be acceptable for automobiles, they are inadequate for aviation. The reasons are as varied as the list above. All come with some form of major drawback, from the weight of the systems, freezing points, flash points¹⁴, or low energy densities compared to the aviation fuel (JP-5) they would be replacing (see Appendix 1, figure 4). The result of most recent experimentation is that DOD and in particular aviation will be petroleum dependent for the foreseeable future. In fairness, tests of a more limited nature are being conducted by the U.S. Air Force and the air forces of several other nations regarding the potential of blended fuels. These fuels consist of a percentage of JP-5 and highly refined bio-diesel (turbine engines do not handle impurities well unlike diesel engines that will run on almost any grade of fuel). Of note the US Air Force recently conducted test of a aviation fuel blend produced partially from liquid natural gas via the gasification process describe later in this paper¹⁵. To date, however, this remains only in the realm of testing, but if blending proves successful it offers the potential to stretch existing and future conventional JP fuel supplies.

Nuclear material does offer some potential. Currently, turbine engine designs powered by non-fissionable material¹⁶ are on the drawing boards. These are not large reactor based power plants found in the U.S. Air Force Aircraft Nuclear Propulsion program (ANP) of the 1950's and 60's, but employ radioactive material as the heat source in place of burning aviation fuel. They are currently being considered to power high altitude reconnaissance aircraft, offering almost unlimited endurance. While these engines would likely have potential draw backs such as weight, or radioactivity shielding requirements for a manned aircraft, the technology, if perfected, would revolutionize military aviation in much the same way the jet engine did in the late 40's and 50's. For the purposes of this paper the aforementioned radioactive agent powered

turbine engine is not considered a viable alternative. This is due to the fact that such technology will not appear in practical form for tactical aircraft for many decades.

Synthetic Fuels: A Realistic Alternative?

The United States' current dependence on liquid hydrocarbon fuels without abundant domestic crude oil supplies is not unprecedented. In pre-WWII Germany, Franz Fischer and Hans Tropsch developed a process to produce liquid hydrocarbon fuel from coal. The so called Fischer-Tropsch (FT) process supplied a substantial amount of Germany's fuels during World War II, particularly after bombing reduced the output of the Ploiesti oil fields and refineries in Romania.

In the FT process, so-called syngas (short for synthetic gas, a mixture of molecular hydrogen and carbon monoxide) is reacted at high temperature in the presence of an iron catalyst to produce a mixture of short- and medium- and long-chain hydrocarbons, carbon dioxide, water, and hydrogen. The short-chain hydrocarbons (so-called tail gas) are not ideal transportation fuels, but can be burned locally to produce the necessary heat for the FT reactions, and can also be used to produce electricity from a gas-turbine generator. The medium-chain hydrocarbons are usable transportation fuels, particularly when blended with additional material derived from the long-chain hydrocarbons (usually waxes) through hydro-cracking. The ability to control the carbon chain lengths derived from waxes allows for the manufacture of ideal transportation fuels such as diesel and jet fuel.

Syngas is easily produced via the partial combustion of coal, which has been gasified and combined with molecular oxygen derived from air. Syngas (then known as water gas) was produced and distributed to homes and businesses in the late 1800s and early 1900s, before

methane supplanted it for safety reasons. The carbon monoxide in syngas made it a very dangerous material. Today, gasification is usually accomplished with pulverized coal and pure oxygen produced by separating air. The nitrogen can either be vented to the atmosphere, or used with some of the hydrogen in syngas to produce ammonia, a nitrate fertilizer feedstock. Importantly, the gasification process serves to separate the sulfur and heavy-metal contaminants found in low-grade coal which makes it undesirable as a raw fuel. Thus, the liquid hydrocarbon fuels produced from coal via gasification and the FT process are intrinsically clean. Use of such fuels will minimize emissions (sulfur and particulates) from internal combustion engines, and will also allow production of clean hydrogen (via fuel reformers) that could supply a fuel cell without poisoning the fuel cell chemistry.

FT fuel production is mature technology. As mentioned above, it was used successfully by WWII Germany on a large scale. Additionally, South Africa was unable to import crude oil in large quantities during the apartheid era; consequently all of South Africa's vehicles have been powered by FT-generated fuels derived from low-grade coal for nearly fifty years. Sasol's FT plant in Secunda, South Africa, produces 150,000 barrels of manufactured fuel per day. China, which also has abundant domestic coal, has essentially purchased the entire world output of coal gasifiers for the past several years to produce fertilizer via the FT process. Finally, commercial oil companies are planning on establishing FT infrastructure in the Persian Gulf to produce liquid hydrocarbon fuel from natural gas which would otherwise be flared off, or liquefied and transported to Liquefied Natural Gas (LNG) terminals at high expense in pressurized tankers. According to Shell Oil, by 2015 the Gulf State infrastructure will produce 900,000 barrels/day of FT-derived liquid hydrocarbon fuels from natural gas. They also point out that the FT process can be used to produce liquid hydrocarbon fuel from virtually any carbon-containing feed stock,

including low-grade tars, biomass, or shale oil; only the preprocessing steps would differ from the gasification process used for coal.

The answer to DOD fuel problems could come in the form of a joint DOD/Private industry collaboration. Beard Generation, a 20-year-old producer of small- to medium- scale project-financed power plants has proposed building an integrated gasification-FT-fertilizer power plant. The plant would produce 28,000 barrels of liquid hydrocarbon fuel a day from 17,000 tons of low-grade coal, 750 tons per day of ammonia, and 475 Mega Watts of net electrical power. The plant would cost \$3 billion dollars, and employ 200 full-time staff. Beard envisions building such plants near rich low-grade coal fields, areas that are typically economically depressed since emission controls have made such coal economically unattractive for power production. Although such plants are relatively small, it would only take about ten such plants to supply all of DOD's present liquid hydrocarbon fuel requirements. Beard claims that commercial financing of such plants will be possible, with adequate internal Return on Investment (ROI) and revenue/debt margins. DOD could catalyze this commercial development of highly desirable infrastructure by making a long term commitment to purchase liquid hydrocarbon fuels at attractive prices. Beard estimates that a 10-year commitment would enable a sale price (for diesel) of \$61/barrel (bbl) (\$1.45/gal); similarly a 15-year purchase commitment would yield \$54/bbl (\$1.29/gal) diesel. Over the term of the commitment, diesel prices would escalate, but only at the rate of long term coal contracts, not at the rate of oil markets.¹⁷ At such prices, given the impending arrival of Hubbert's Peak, DOD would risk little by making a purchase commitment. In fact, long-term purchase contracts for FT-derived liquid hydrocarbon fuels could provide a highly favorable hedge against volatile market prices for fuel.

Currently our nations projected coal reserves stand at approximately 9.2 billion short tons¹⁸ or roughly converted the equivalent of 15 billion barrels of refined fuel. In addition, the U.S. oil shale reserve is estimated to be equivalent to two trillion barrels of oil.¹⁹ Combined, these resources contain more than enough oil to provide the Nation and DOD well into the future, but these reserves are in name only if we do not possess the infrastructure to utilize them. While the Marine Corps is not in a position to dictate DOD fuel policy, we should be prepared to vigorously support such alternative oil sources to ensure an adequate and stable supply of fuel not affected by dramatic fluctuations in crude oil supplies and prices fluctuations.²⁰

DOD as a Consumer of Oil

The United States consumes over 16 million barrels (almost 700 million gallons) of petroleum products per day. As a reference point, China, the second largest consumer, uses about 6.5 million barrels a day. Nationwide, about half of the fuel in the U.S. is consumed in automobiles and trucks. The federal government's petroleum demand is a mere two percent of this total, at 330,000 barrels (nearly 14 million gallons) per day. Within the federal government, the DOD is the largest consumer, requiring about 300,000 barrels per day for normal *peacetime* operations across the four DOD services. Aircraft consume approximately 73 percent of DOD petroleum products.²¹

In the present situation of high oil prices and high tempo operations supporting the Global War on Terror (GWOT), the DOD's ability to manage the cost of fuel in order to meet the demands of the services has taken the form of Congressional supplemental appropriations.²² If not for these additional Congressional funds the Navy and Marine Corps (in theory) would have been forced to sell back 54,000 flight hours to pay for the increased fuel consumption of, at

a cost equivalent to approximately 283 million dollars²³. Simply put, we cannot rely on such funding supplementals as they will not likely be available when operations in Iraq come to an end. Our current system for projecting, budgeting and purchasing fuel for the Navy and Marine Corps is simply not flexible enough to handle rapidly increasing oil prices. As discussed earlier in this paper there are no good alternatives to liquid hydrocarbons when it comes to aviation. Liquid hydrocarbons have ideal properties and will be needed by U.S. military aviation for the foreseeable future.

U.S. fuel stocks are overwhelmingly obtained by refining crude oil and the majority of the fuel is produced from imported oil, making the United States heavily dependent on overseas production infrastructure. Frequently this infrastructure is located in politically unstable or in unfriendly regions like the Middle East, western Africa and Venezuela. The risk is compounded by a complicated transportation system and a domestic crude oil refining infrastructure now operating at near capacity. As developing economies in Asia rapidly increase their consumption of oil-derived hydrocarbon fuels, they will be competing with the United States, which now dominates world oil consumption. Such competition will drive prices ever higher, and perhaps lead to intermittent fuel shortages as production fluctuates. Clearly, this competition for resources also provides oil producers with multiple options for selling their products, but raises the possibility that the United States could face shortages resulting from shifts in political alignments within the producing nations.²⁴

All the issues addressed above are exacerbated by the assumed inevitable exhaustion of crude oil, which is a finite resource. There are a wide range of estimates for when Hubbert's Peak will occur for world oil production. In general, commercial oil companies tend to place the peak farther out in time, whereas government and academic sources estimate the peak will be

sooner. Basing U.S. economic and military use of liquid hydrocarbon fuels exclusively on crude oil feed stocks will therefore become problematic in the near future.

The impact of this on the United States and the DOD may very well result in a major restructuring of the armed services, not due to philosophical or technical reasons, but simply because the United States may not be able to afford the armed services we currently have. This is particularly evident when one looks at aviation as a whole, which is the major consumer of oil in the Department of Defense. All the new aviation platforms, from the F-22 at \$116 million per copy to the F-35 Joint Strike Fighter, approaching \$60 million per copy, to the new UH-1Y, AH-1Z and the under development CH-53K are very expensive. How much farther will it go before the Congress and the American people ask the question; “If we are so joint in our operations, why do we need four separate services? And three separate air forces with so many different aircraft?”

Marine Corps Aviation

The Marine Corps is in the midst of the largest aircraft replacement program in our history. Every single Marine airframe except perhaps the EA-6B and the CH-53E²⁵ has an immediate successor either rolling off or very soon to roll off assembly lines and onto our flight lines. While a direct comparison of these new aircraft to the aircraft they are replacing would be considered by some as comparing apples and oranges, one truth is self evident. They all use more fuel than the airplanes they are replacing.²⁶

In the end we must fly in order to maintain readiness and proficiency. The Marine Corps may very well face a Catch 22; as fuel resources become more constrained, their cost spirals up. The increased cost of fuel will require a greater share of limited funds, making it increasingly

difficult to acquire enough fuel to support training, operations, and the cost of new aircraft acquisitions.

This “crisis” is not without precedent. The effects of the 1973 Oil embargo and its resultant fuel shortage forced the Navy to cut at-sea time by 20 percent and the Air Force to cut flight time by 33 percent.²⁷ The situation became so critical in late 1973²⁸ that the DOD invoked the Defense Production Act of 1950, which gives it the authority to take first priority in domestic petroleum production. As one can imagine this did not happen without controversy as the newly appointed Energy Administrator demanded that DOD surrender 1.5 million barrels of its 19.7 million barrel jet fuel supply for use by domestic airlines. In the end a compromise was made by Secretary of Defense James R. Schlesinger and the DOD surrendered 900,000 barrels. It is likely that a similar situation today would be even less politically and economically palatable than in 1973. It also would not be as quickly alleviated as in the mid 70s since those fuel supplies would continue to become increasingly scarce.

In the event that the DOD did not act when it had the opportunity to secure a reliable source of fuel, the immediate solution would be for the DOD to cut back on training across the board in an attempt to minimize the operational impact. The length of time these restrictive measures would be imposed on the services is a critical issue. As in 1973, even a short term cutback of training has an impact on readiness; however, if this cutback was extended into the span of years then the impact on training would be significant. The experience base that allows us to create successful generations of pilots would not be lost in its entirety, but it would certainly affect our ability to train high quality pilots for several years, lasting past the point at which normal training rates returned. The key to the American success in the air has not always been one of technical superiority, but has always been found in the superior fighting and flying skills

of US aviators. In turn the American way of war has relied heavily on American supremacy of the air as a major component to its success, is this something we are willing to forfeit in the future?

There are two main areas the Marine Corps can focus on to mitigate the impact of reduced flight hours due to higher fuel cost. The first is efficiency, which can be broken down into four steps. The first step is the full funding of the Marine Corps Aviation Simulation Master Plan (MCASMP). The ongoing effort to acquire networked simulation with fully functional simulators capable of supporting advanced pilot training is vital in making up for lost flight hours. The Marine Aviation Training Systems Squadron (MATSS) provides the critical framework that will ensure we get the most out of the MCASMP when it comes to improved simulator instruction, training and standardization. The second step is a major review of the Mission Essential Task List (METL) and Training and Readiness (T&R) requirements that support them for all aircraft. There must be a ruthless evaluation, cutting any excess, while still maintaining the METL's and actual flight hours and training that are critical. The third step should be to look at programs that will improve the overall reliability of our aircraft systems with the goal of reducing aircraft downtime and maintenance man-hours spent on the aircraft. Any saving from these programs could be redirected to make more funds available for aviation fuel. The fourth step is to keep pilots in their squadrons longer improving proficiency levels.

The second area focuses on unconventional ideas. Unmanned Aircraft Systems (UAS) such as the Pioneer, Predator, and Hunter have been used mainly in the reconnaissance role and occasionally in an armed role. Their flexibility, long duration flights, small silhouettes and low operational cost make them attractive platforms in a resource constrained environment. The Marine Corps should ensure that any squadron-sized tactical UAS it procures is capable of

conducting both reconnaissance and attack missions. Today no one would consider the UAS or Unmanned Combat Aerial Vehicle (UCAV) as thinking outside the box. However, the idea of a highly automated Unmanned Aerial Logistics vehicle (UALV) is bound to generate skeptics. In essence large Assault Support aircraft like the CH-46/53 and MV-22 are very expensive to operate. At times they are used for logistical support missions that cost more to conduct than the items delivered. A family of automated UALVs could handle large portions of the non-passenger related logistical flights. In short, the acquisition of a family of UALV's should be cheaper than manned airframes and will have an overall operational cost much lower than manned systems. The financial savings would come from fewer flight hours, lower maintenance and fewer costly parts required to maintain and operate current Assault Support Airframes.²⁹

Conclusion

As exemplified by the quote from Ecclesiastes noted: "there is nothing new under the sun," Almost every "novel" idea envisioned for this paper turned out not to be really "novel" at all. Most of the innovations discussed, can be found in Congressional hearings, planning studies, and professional journals dating back to the 1970s. The truly frustrating aspect, however, is not the lack of novelty of the ideas but the fact that so little appears to have been done in the last 30 plus years to address the underlying issues that warrant further Congressional hearings, planning studies, and journal articles. One cannot help but draw a parallel between our current situation in dealing with insurgencies in Iraq and Afghanistan. Counter Insurgency and Small Wars was a topic which has only gained acceptance when DOD is faced with a profound need for it. In the case of fuel supply DOD can be proactive in addressing this critical requirement and potentially devastating effects of a rapid decrease in supply. One does not have to stretch their imagination too far to see an example of how devastating an effect an Al-Qaeda terrorist strike on Saudi

Arabian or Mexican oil refineries would have on oil prices and in turn the world economy.

Consider what a cut-off of oil from Venezuela under the verbose and erratic leadership of Hugo Chavez would have on our country? Or a shut down of Nigerian oil supplies due to civil unrest in the Niger delta? The instability and the potential are real for events like this to happen. Even if some may consider the risk to be low, the effects of just one of these events would be dramatic and long term. The effect of a combination would be catastrophic. How much of our national security are we as a nation willing to risk?

The Marine Corps cannot force the DOD into developing alternative fuel supplies, but we can act as advocates in our own self interest. Congress is unlikely to authorize the DOD to use “unlimited” funds to pay for all contingencies. If Hubbert’s Peak is indeed around the corner it will not matter as the price increase could easily outpace the funding process. It is in the nation’s vital interest for the DOD to make a long term commitment to develop and acquire a secure fuel supply independent of crude oil.

At some point the war in Iraq is going to come to an end. The cost of refitting and repairing the service’s equipment and manpower will be high \$29 Billion in 2007 alone.³⁰ If past experiences are an accurate guide to the future then at the end of Operation Iraqi Freedom we should expect the politicians to look for a peace dividend or, at a minimum, a re-allocation of resources. DOD spending is currently at record levels. We may very well find that the nation’s willingness to pay the price for our current defense structure is unsupportable in the future. If we do not ask hard questions now, and explore the alternatives, then we may find our sister services coming to the table with a stronger hand. As the famous Prussian General Helmuth Graf Von Moltke “the Elder” remarked: “A mistake in the original assembly of the armies can hardly be put right again during the whole course of the campaign.”³¹ A major mistake in the Marine

Corps future planning and positioning for funding can hardly be put right again when it comes to our future. A miscalculation on our part could end Marine Aviation as we know it today.

The Marine Corps has no greater asset than its manned aircraft. The flexibility and firepower Marine aviation brings to the fight in support of his ground brethren is truly awesome. As a former Marine Expeditionary Unit Commanding Officer once said “the ACE is the big M and big F of the MAGTF, without the ACE the MAGTF lacks big MOBILITY, without the ACE the MAGTF lacks the big FIREPOWER, without the ACE in the MAGTF the Marine Corps lacks a reason to exist.”

Appendix 1

Figure (1)

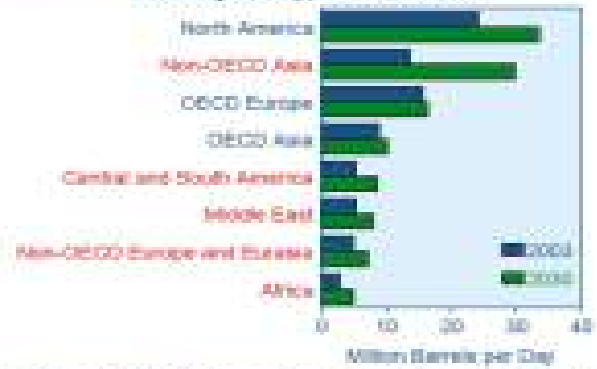
Figure 36. World Oil Consumption by Sector, 2003-2030



Sources: 2003: Derived from Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2003), web site www.eia.doe.gov/coal; Projections: EIA, *System for the Analysis of Global Energy Markets* (2006).

Figure (2)

Figure 37. World Oil Consumption by Region and Country Group, 2003 and 2030



Sources: 2003: Energy Information Administration (EIA), *International Energy Annual 2003* (May-July 2003), web site www.eia.doe.gov/coal; 2030: EIA, *System for the Analysis of Global Energy Markets* (2006).

Figure (3)

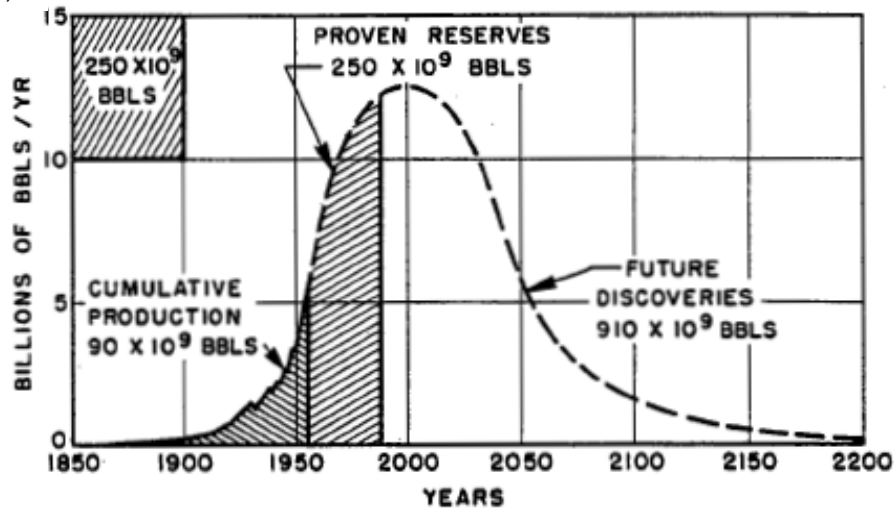


Figure 20 - Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

Figure (4)



Energy Density of Fuels

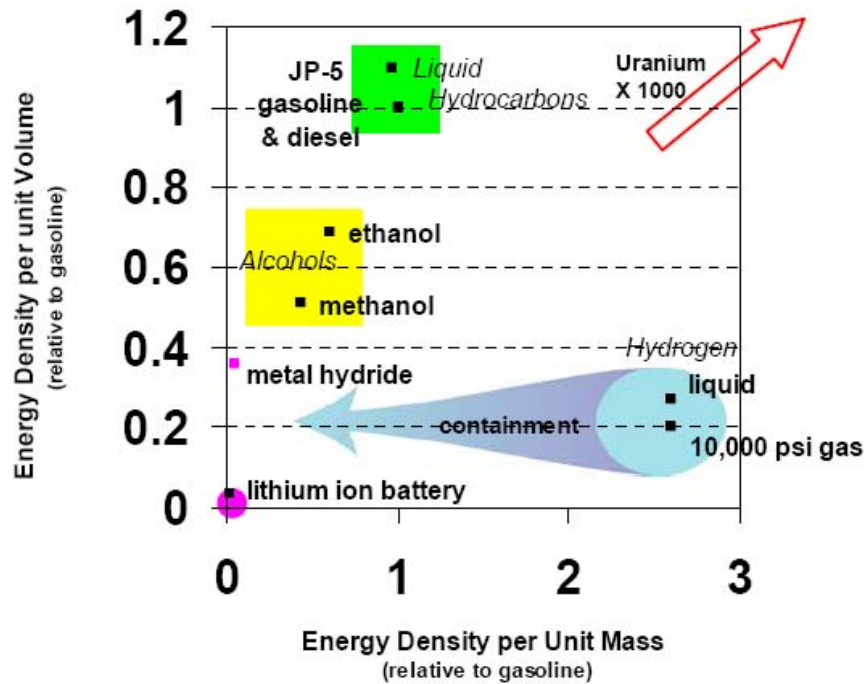


Table 1: Projections of the Peaking of World Oil Production

Projected Date	Source of Projection	Background & Reference
2006-2007	Bakhtari, A.M.S.	Oil Executive (Iran) ¹
2007-2009	Simmons, M.R.	Investment banker (U.S.) ²
After 2007	Skrebowski, C.	Petroleum journal editor (U.K.) ³
Before 2009	Deffeyes, K.S.	Oil company geologist (ret., U.S.) ⁴
Before 2010	Goodstein, D.	Vice Provost, Cal Tech (U.S.) ⁵
Around 2010	Campbell, C.J.	Oil geologist (ret., Ireland) ⁶
After 2010	World Energy Council	World Non-Government Org. ⁷
2012	Pang Xiongqi	Petroleum Executive (China) ⁸
2010-2020	Laherrere, J.	Oil geologist (ret., France) ⁹
2016	EIA nominal case	DOE analysis/ information (U.S.) ¹⁰
After 2020	CERA	Energy consultants (U.S.) ¹¹
2025 or later	Shell	Major oil company (U.K.) ¹²

Endnotes

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- ¹ Department of Energy. Energy Information Administration. February 2006. *Petroleum*. Washington: Available: http://www.eia.doe.gov/oil_gas/petroleum/info_glance/petroleum.html
- ² Department of Energy. Energy Information Administration. February 2006. *International Energy Outlook 2006*. Washington: Available: <http://www.eia.doe.gov/oiaf/ieo/oil.html>
- ³ Hubbert, Marion King “*Nuclear Energy and the Fossil Fuels*” Shell Development Company Exploration and Development Co. March 1956.
- ⁴ This is true of the United States. Several other countries in particular China and Canada have invested heavily in Gasification plants. China utilizes them for the production of fertilizer. Canada is currently producing 560,000 barrels of oil a day from its Vast Alberta Oil Sands deposits. Some experts predict that by 2020 Canada will be producing 3 million barrels a day from this resource.
- ⁵ This is true only if the price of oil falls below the production price of oil produced in a gasification plant. Currently Canada produces 1 barrel of oil from its oils sands at \$20 a barrel not including the cost of infrastructure. As long as oil prices remain high then fuel from gasification will remain economically viable.
- ⁶ Questioning the impact of high oil prices on the Department of Defense and the individual services is important and essential. However, it is beyond the scope and limitations placed on this paper.
- ⁷ Deffeyes, Kenneth S. “*Hubbert’s Peak: The Impending World Oil Shortage*” New Jersey: Princeton University Press, 2001 Page 1
- ⁸ Hubbert, Marion King “*Nuclear Energy and the Fossil Fuels*” Shell Development Company Exploration and Development Co. March 1956. Page 22.
- ⁹ Deffeyes, Kenneth S. “*Hubbert’s Peak: The Impending World Oil Shortage*”. New Jersey: Princeton University Press, 2001 Page 1
- ¹⁰ A more extensive list of advocates for Hubbert Peak Oil Theory can be found in Steve Andrews. “Peak Oil Theory is Garbage” Energy Bulletin. Online. Internet. Available: <http://www.energybulletin.net/20418.html> despite the title of the article it is for Hubbert’s Peak Oil Theory.
- ¹¹ Lynch, Michael C. “Crying Wolf: Warning about Oil supply” MIT Online. Internet. Available: <http://sepwww.stanford.edu/sep/jon/world-oil.dir/lynch/worldoil.html> Page 2
- ¹² “Mexico discovers huge oil field” BBC News 15 March 2006: Available: <http://news.bbc.co.uk/go/pr/fr/-/2/hi/americas/4808466.stm>
- ¹³ Isidore, Chris “Major US Oil source is tapped” CNN Money 5 September 2006: Available: http://money.cnn.com/2006/09/05/news/companies/chevron_gulf/index.htm?cnn=yes
- ¹⁴ Definition of Flash Point in reference to physical chemistry is: The lowest temperature at which the vapor of a combustible liquid can be made to ignite momentarily in air.
- ¹⁵ Air Force Link, “B-52 test alternative jet engine fuel” California: Available: <http://www.af.mil/news/story.asp?id=123027415>
- ¹⁶ The radioactive material cannot be utilized in a nuclear weapon. However it could potentially be used in a dirty bomb type scenario.

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- ¹⁷ Naval Research Advisory Committee Report. "Future Fuels: April 2006" Washington. Pg 55-56
- ¹⁸ Department of Energy. Energy Information Administration. Washington: Available: <http://www.eia.doe.gov/>
- ¹⁹ Department of Energy. "Oil Shale Activities". Washington:
Available: http://www.fe.doe.gov/programs/reserves/npr/NPR_Oil_Shale_Program.html
- ²⁰ The chapter "Synthetic fuels a realistic alternative" draws heavily from the concise writing and research in the Naval Research Advisory Committee Report. "Future Fuels: April 2006" Washington. Pg 55-57
- ²¹ Detailed break down of oil consumption in the U.S. and in DOD. Naval Research Advisory Committee Report. "Future Fuels: April 2006" Washington. Pg 19
- ²² To obtain additional funding after regular appropriations have been enacted, the president submits requests for supplemental appropriations to the Congress. Supplemental appropriations have been considered technical adjustments to various unpredictable events and have received little attention in studies of the budgetary process.
- ²³ Based on a phone conversation with N-43 Fleet Readiness Office. The Department of the Navy exceeded its standard Flight Hour Program (FHP) by 4,834 hours. The remaining 50k hours are operational hours paid for by supplemental's to the normal budget directly for cost related to the GWOT. Cost calculation based on average total cost per flight hour (TCPH) cost of \$5506.27 according to the OP-20 Version 1773 dated 18 July 2006 Current and Projected Fuel Consumption for the Navy and Marine Corps 2006-2012. Washington DC: CNO 2006
- ²⁴ Naval Research Advisory Committee Report. "Future Fuels: April 2006" Washington. Pg 51-52
- ²⁵ The EA-6B replacement has not been identified, proposals include a variant of the F-18E/F call the EA-18G and possibly a variant of the F-35. The CH-53E has a approved replacement designated the CH-53K. The CH-53K is scheduled to achieve its Initial Operating Capability (IOC) in FY 2015.
- ²⁶ The comparison is fuel flow (FF) or pounds per hour (PPH) of fuel per equivalent sortie. The AH-1Z, UH-1Y, MV-22, F-35 STOVL all use more fuel to conduct an identical sortie than their predecessors. I do not argue that the new platforms also have much greater capabilities in some areas than their predecessors. The one exception to this is likely the KC-130J, with its improved propellers and design it is very likely more fuel efficient than its predecessor.
- ²⁷ Jefferies, Captain Chris L. USAF "Defense Policy in a world of Limited Resources" Air University Review July / August 1975 Page 3.
- ²⁸ House Armed Services Committee "*Report by the Special Subcommittee on Department of Defense Energy Resources and Requirements.*" 93rd Congress, Second Session, Washington GPO, June 1974 Page 3 of Finding and Conclusion reported that the Arab Oil Embargo reduced the DOD foreign oil procurement from 315,000 barrels a day to 50,000 barrels a day. Petroleum stocks of the DOD were reduced to dangerously low levels by the last quarter of 1973. Peacetime operating stocks were virtually exhausted, and pre-positioned war reserve stocks were used to continue operations in the absence of current deliveries. A total of 8.9 million barrels was drawn from reserve stocks during the last 6 months of 1973. Also of note is in January 1974 the Federal Energy Office would not approve the DOD request for an allocation of 8.9 million barrels to replenish its reduced reserve stock. At that time commercial airlines were allocated 85%, and later 95% of their 1972 jet fuel consumption.
- ²⁹ To fully explore the idea of the UALV is beyond the scope of this paper and is something the author intends to address in a future paper.

³⁰ Wilson, George C. “*Forward Observer: Many Dollars, No Sense*” Congress Daily 18 September 2006. Online. Internet. Available: <http://www.govexec.com/dailyfed/0906/091806cdaml.htm>

³¹ Quoted in “The Operational Art and the Elder von Moltke’s Campaign Plan for the Franco-Prussian War,” Bradley J. Meyer, Unpublished paper page 22.

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